Analysis and proposal of empirical magnitude scaling relationships (EMSR) for the seismic potential of earthquakes in Central America

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1. Introduction

- **Abbreviated but integral component of seismic hazard analysis**, being an important issue for the definition of source models into the hazard estimation.
- Relevant to **define the earthquake scenario for deterministic approaches** and for modeling the **ruptures distribution in probabilistic methods**

Area source

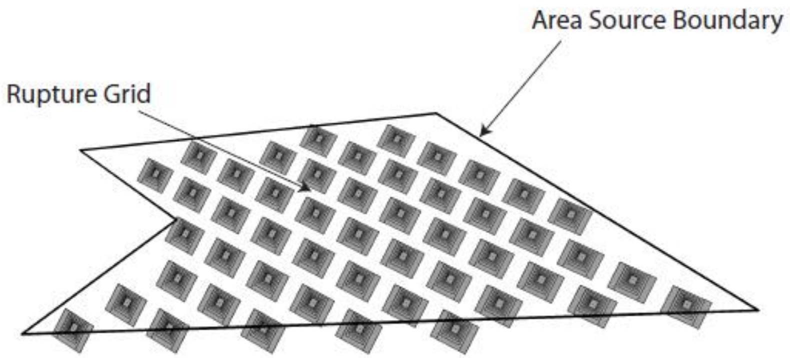


Figure 3.2 – *Earthquake ruptures generated by an area source in the OQ-engine. Ruptures are distributed uniformly over a regular grid within the area. In this plot, for better visualization, ruptures are modeled only according to a single nodal plane and hypocentral depth, but actual calculations may involve multiple orientations and hypocentral depths. Ruptures originating from different grid nodes may also overlap and cross each other.*

Simple Fault

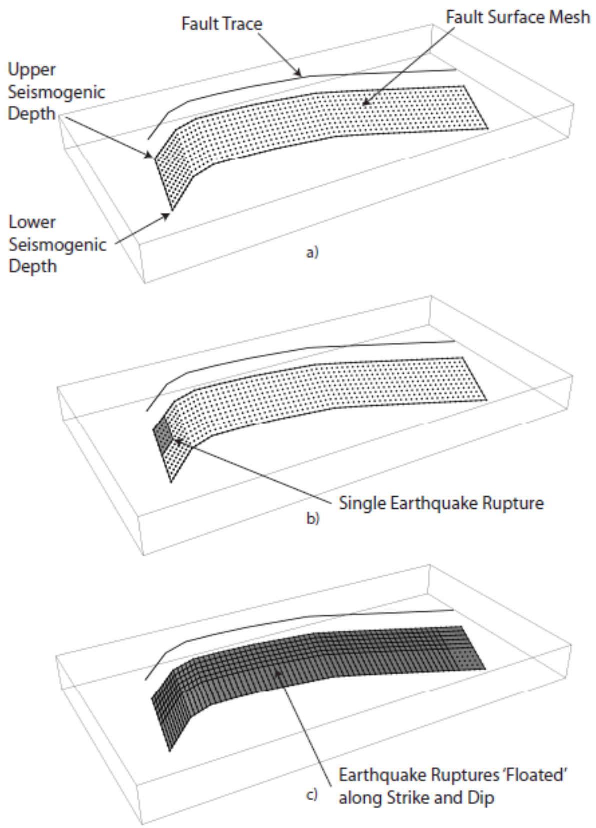
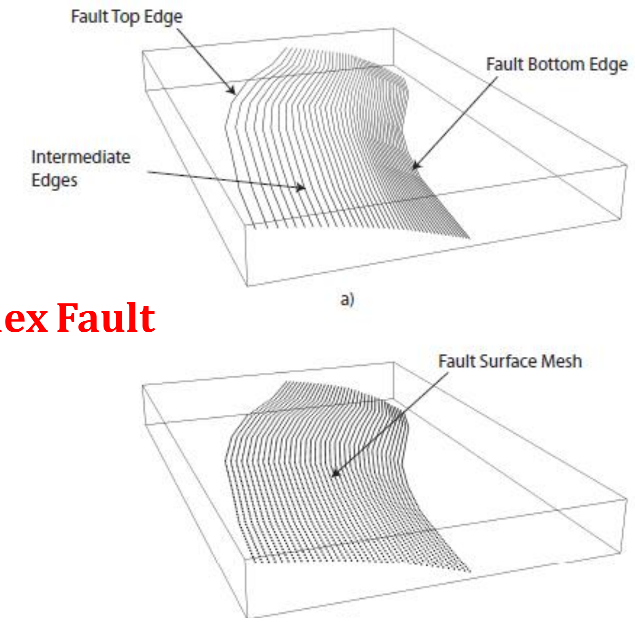


Figure 3.3 – *Simple Fault source in the OQ-engine. The fault surface is obtained by translating the fault trace from the Earth's surface to the lower seismogenic depth with an inclination equal to the dip angle. The upper seismogenic depth delimits the fault top edge. A mesh representation of the fault surface is then constructed a). An earthquake rupture is defined as a portion of the fault surface b), and all possible rupture locations are simulated by floating the rupture surface both along strike and along dip c)*

Complex Fault



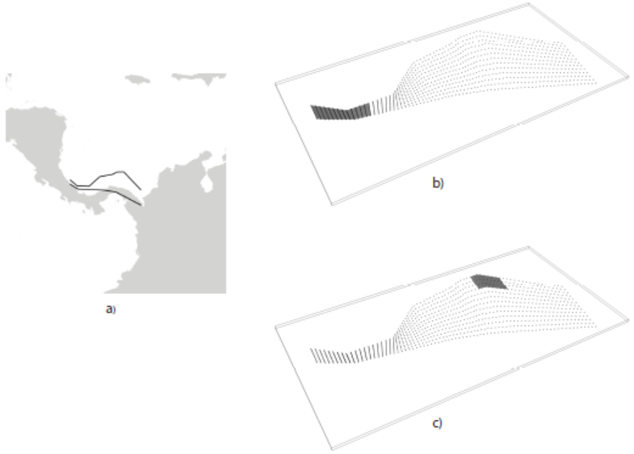


Figure 3.5 – *a) Example of Complex Fault source representing subduction interface fault in North of Panama (Petersen et al., 2010). The mesh modeling a M = 7.7 event is depicted in the eastern part b) and in the western part c)*

Characteristic Fault

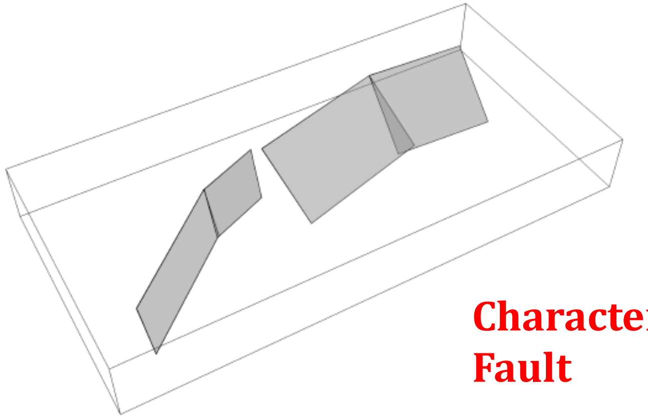


Figure 3.6 – *Example of Characteristic Fault sources defined through a collection of planar surfaces modeling a multi-segment rupture*

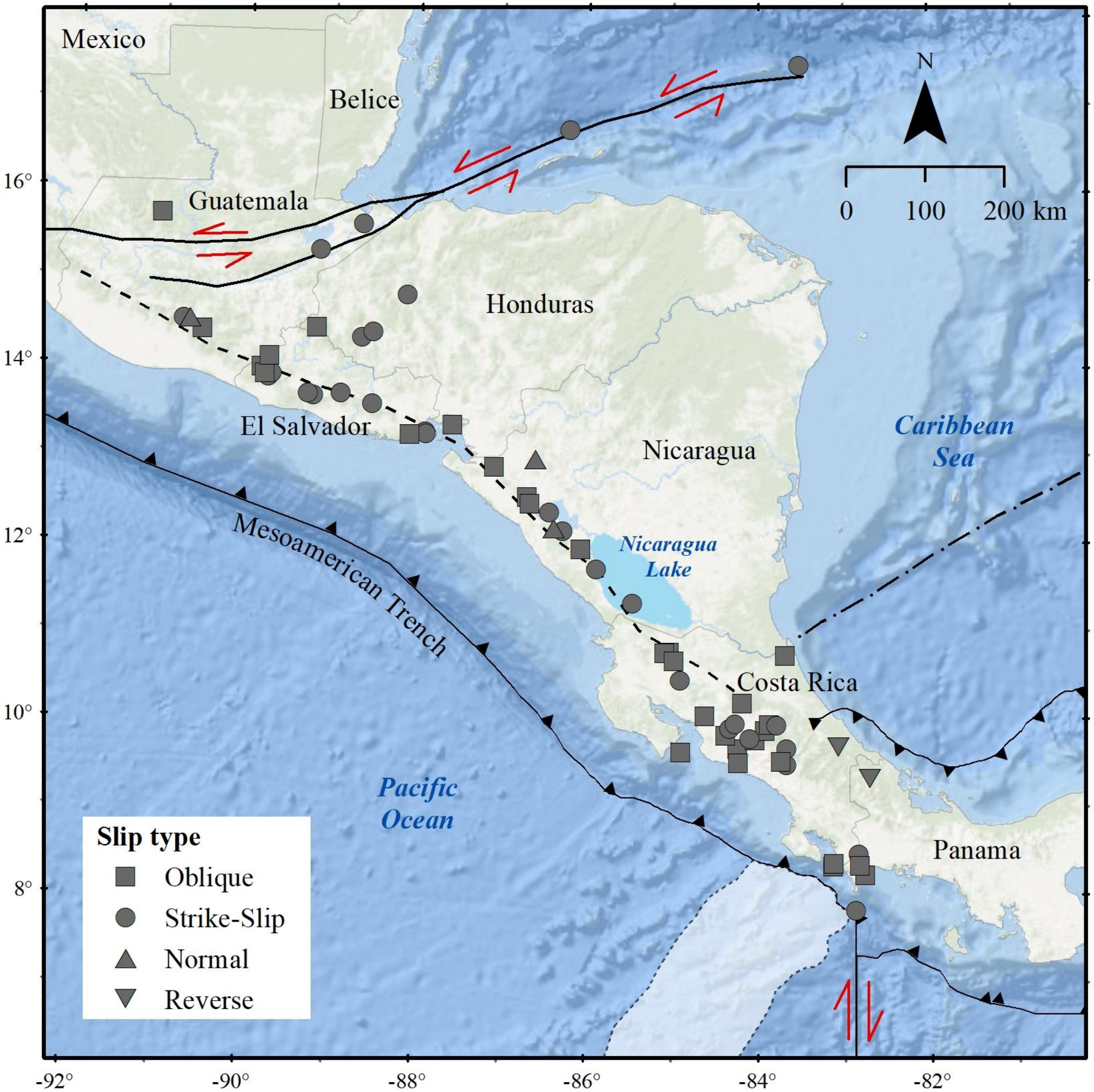
Source: OpenQuake manual (GEM, 2020)

2. Earthquake database

- Subduction zone with transform faults and near to triple points
- 64 crustal earthquakes, between 1972 and 2021.
- Magnitudes between 4.1 and 7.7 Mw, and 19 earthquakes above 6.0 Mw

Event count:
- 24 Costa Rica
- 5 Panama
- 12 El Salvador
- 5 Guatemala
- 7 Honduras
- 11 Nicaragua

- Weight scheme Q1, Q2 and Q3 according to:
  - Year of the earthquake
  - Related studies
  - Aftershocks
  - Knowledge of the fault
  - Magnitude



3. Compilation and selection of EMSR

19 EMSR compiled

Criteria for use:

1. *Similar tectonic context*
2. *Wide use worldwide*
3. *Year of publication*
4. *Preference in Mw*
5. *Use in previous studies for the region*

ID	EMSR
BON84	Bonilla et al. (1984)
WC94	Wells & Coppersmith (1994)
AND96	Anderson et al. (1996)
STIR96	Stirling et al. (1996)
AJ98	Ambraseys & Jackson (1998)
STIR02	Stirling et al. (2002)
DR04	Dowrick & Roades (2004)
PC04	Pavlides & Caputo (2004)
PAP04	Papazachos et al. (2004)
HB08	Hanks and Bakun (2008)
WESN08	Wesnousky (2008)
STIR08	Stirling et al. (2008)
LEON10	Leonard (2010)
YM11	Yen and Ma (2011)
OZT14	Ozturk (2014)
STAF14	Stafford (2014)
AND17	Anderson et al. (2017)
THINB17	Thingbaijam et al. (2017)
BRENG19	Brengman et al. (2019)

Surface/geological *rupture parameters*

Surface rupture length (LRSup)

Slip Rate (SR)

Maximum surface displacement (dMax)

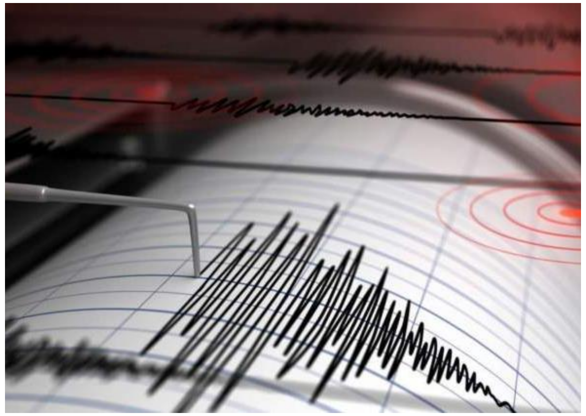
Subsurface/seismological *rupture parameters*

Subsurface rupture length (LRSub)

Rupture Width (W)

Rupture area (AR)

Subsurface displacement (dSub)

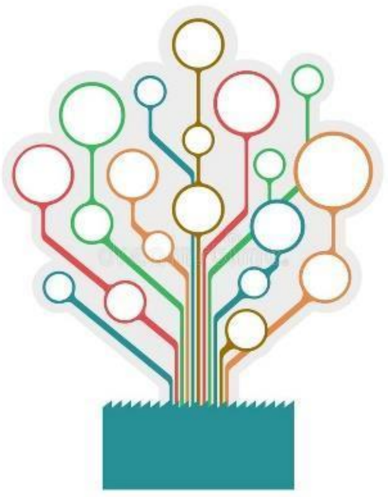


4. Fit analysis of the EMSR used

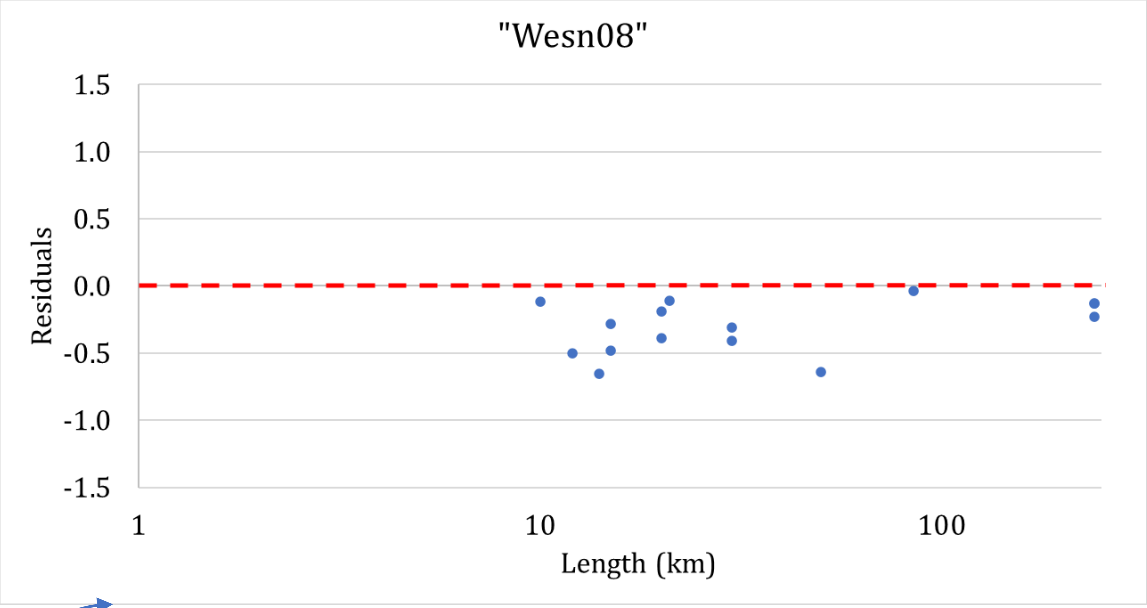
Classification into four categories: A, B, C and D

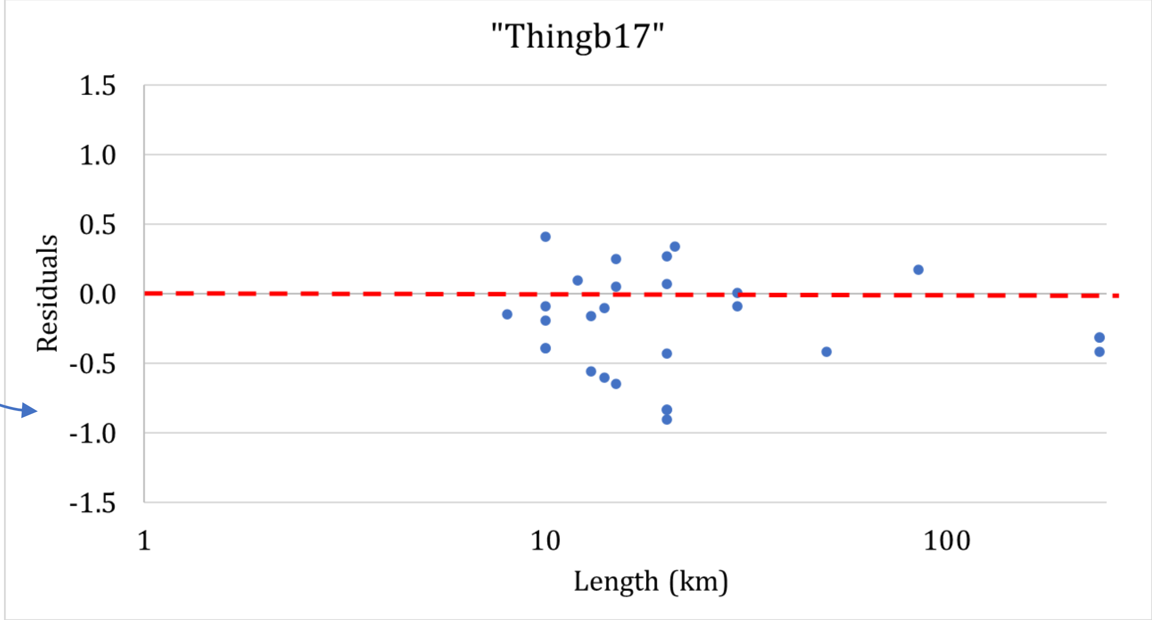
Based on the mean (AVG), the median (MED), the mean square error (MSE) and the standard error (SE) of the residuals.

- Class A equations:
  - AVG and MED must not be off zero by more than 0.2
  - MSE not greater than 0.25
  - SE must be less than 0.5
- Class B equations:
  - AVG and MED must not be off zero by more than 0.3
  - MSE not greater than 0.4
  - SE must be less than 0.8
- Class C equations:
  - AVG and MED must not be off zero by more than 0.4
  - MSE not greater than 0.5
  - SE must be less than 1.0
- Class D equations:
  - Those who do not meet the criteria of any of the above categories.



Surface rupture length (LRSup)





4. Fit analysis of the EMSR used

Surface rupture length (LRSup)

EMSR	Weigth
THINB17	0.5
WESN08	0.4
AND96	0.1

EMSR	Events	AVG	MED	MSE	SE	Class
THINB17	28.00	-0.22	-0.17	0.18	0.42	B
WESN08	15.00	-0.31	-0.28	0.13	0.36	C
AND96	17.00	-0.35	-0.38	0.19	0.44	C
BRENG19	29.00	-0.43	-0.41	0.31	0.55	D
WC94	51.00	-0.98	-1.04	1.27	1.13	D
STIR02	45.00	-1.21	-1.32	1.80	1.34	D

Q: 1, 2 and 3

EMSR	Events	AVG	MED	MSE	SE	Class
THINB17	27.00	-0.23	-0.19	0.18	0.43	B
WESN08	14.00	-0.30	-0.26	0.12	0.35	B
AND96	16.00	-0.34	-0.38	0.19	0.44	C
WC94	43.00	-0.89	-0.97	1.10	1.05	D
STIR02	40.00	-1.16	-1.28	1.68	1.29	D
BRENG19	28.00	-0.44	-0.44	0.31	0.56	D

Q: 1 and 2

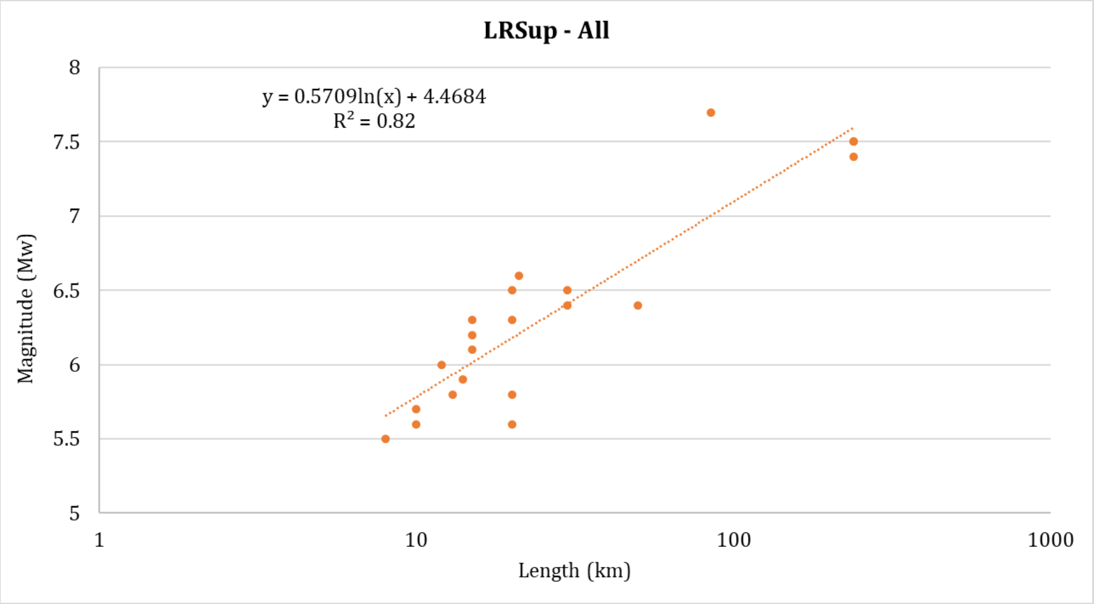
EMSR	Events	AVG	MED	MSE	SE	Class
THINB17	15.00	-0.09	0.01	0.15	0.39	A
WESN08	9.00	-0.29	-0.28	0.12	0.34	B
AND96	10.00	-0.27	-0.26	0.17	0.41	B
BRENG19	15.00	-0.31	-0.22	0.24	0.49	C
WC94	18.00	-0.62	-0.61	0.68	0.82	D
STIR02	18.00	-0.95	-0.91	1.25	1.12	D

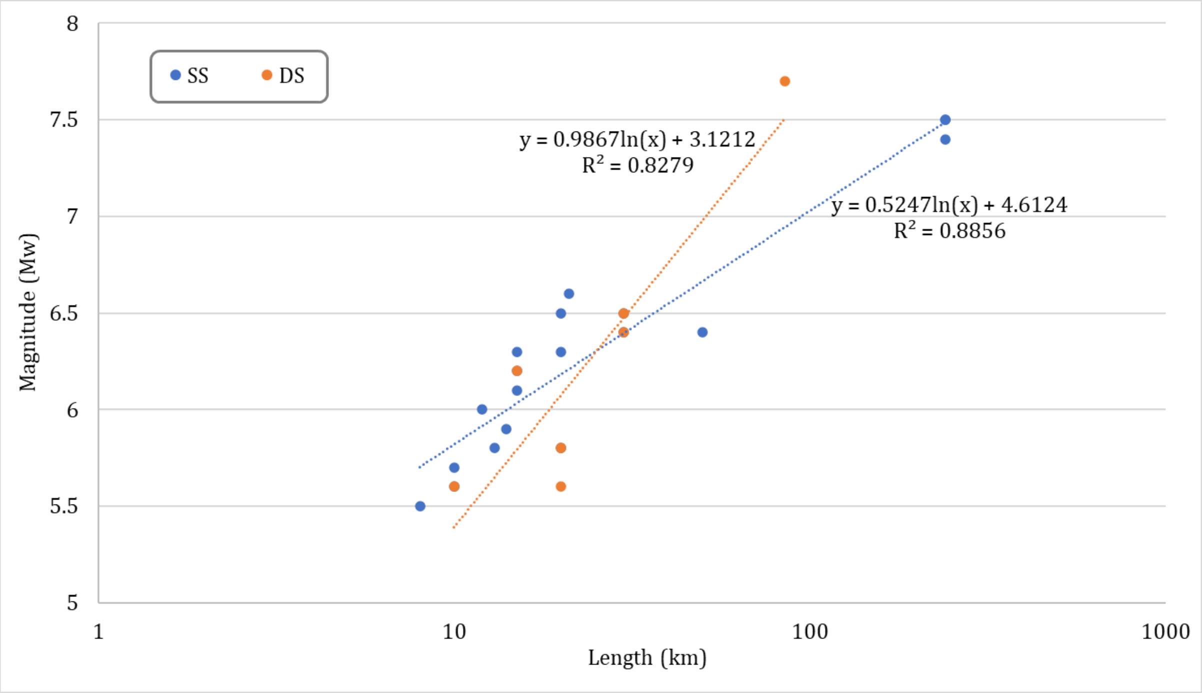
Q: 1

5. EMSR proposal for Central America

Surface rupture length (LRSup)

Mw 5.5 to 7.7





LRSup (km)	All (Mw)	SS (Mw)	DS (Mw)
5	**5.4**	**5.5**	**4.7**
10	**5.8**	**5.8**	**5.4**
15	**6.0**	**6.0**	**5.8**
20	**6.2**	**6.2**	**6.1**
25	**6.3**	**6.3**	**6.3**
30	**6.4**	**6.4**	**6.5**
40	**6.6**	**6.5**	**6.8**
50	**6.7**	**6.7**	**7.0**
75	**6.9**	**6.9**	**7.4**
100	**7.1**	**7.0**	**7.7**
150	**7.3**	**7.2**	**8.1**
200	**7.5**	**7.4**	**8.3**

All: 21 events - Mw 5,5 to 7,7

Mw= 0.5709*ln(LRSup) + 4.4684

SS: 19 events - Mw 5.5 to 7.5

Mw= 0.5247*ln(LRSup) + 4.6124

DS: 7 events* - Mw 5.6 to 7.7

Mw= 0.9867*ln(LRSup) + 3.1212

6. Final remarks

- The best characterized rupture parameters were **surface and subsurface rupture length**, **rupture width, and rupture area**.
- **Slip rates optimize the calculation when they are well determined**, otherwise they introduce error in the estimates.
- **The use of logics trees** of the two or three best ranked equations is suggested.
- We also recommend **the use of the EMSRs proposed in the seismic hazard analysis** for Central America.
- A **detailed review of the historical seismicity** is recommended, as well as consider both, the **segment and the maximum length of the faults**.
- The analysis of the **best-fit relationships** suggest that in Central America the necessary **rupture area is considerably larger** than other regions, for example, New Zealand.

Thank you!

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ESTRUCTURA Y EVOLUCIÓN 4D DE LA LITOSFERA EN AMÉRICA CENTRAL

KUK AHPAN

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UNIÓN EUROPEA
FONDO EUROPEO DE DESARROLLO REGIONAL
AGENCIA ESTATAL DE INVESTIGACIÓN